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(54) **SYSTEM AND METHOD FOR UNLOCKING AN ENCRYPTION KEY CHAIN WITHOUT COMPROMISING SECURITY**

(71) Applicant: **SAP SE**, Walldorf (DE)

(72) Inventors: **Martin Schindewolf**, Walldorf (DE); **Meinolf Block**, Heidelberg (DE); **Christoph Höhner**, Schwetzingen (DE); **Sascha Zorn**, Neulußheim (DE)

(73) Assignee: **SAP SE**, Walldorf (DE)

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(51) **Int. Cl.**

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G06F 16/27	(2019.01)
G06F 16/25	(2019.01)
G06F 21/62	(2013.01)

(52) **U.S. Cl.**
CPC ***H04L 9/0825*** (2013.01); ***G06F 16/25*** (2019.01); ***G06F 16/278*** (2019.01); ***G06F 21/6218*** (2013.01); ***H04L 9/0822*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 9/0825; H04L 9/0822; G06F 16/25; G06F 16/278; G06F 21/6218; G06F 21/6209
See application file for complete search history.

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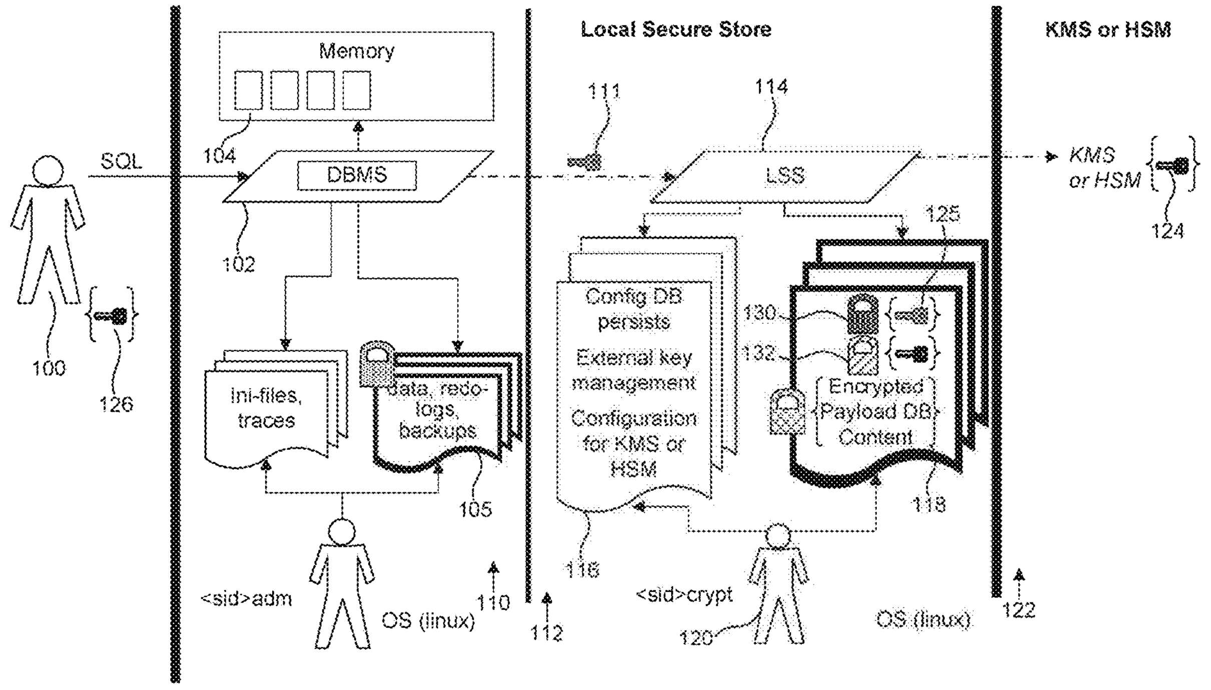
Primary Examiner — Abiy Getachew
(74) *Attorney, Agent, or Firm* — Sterne, Kessler, Goldstein & Fox P.L.L.C.

(57) **ABSTRACT**

The system described herein provides for storing the databases and encryption keys for decrypting the data in the databases into two separate partitions. In an embodiment, the first partition includes the databases while the second partition includes a configuration database and a payload database. The payload database stores a data encryption key for decrypting the data stored in the databases. The payload database is encrypted and may be decrypted using a body encryption key. The body encryption key itself is encrypted twice. In the first instance a key encryption key is generated and in the second instance a second access key is generated. The key encryption key or the second access key may be used to decrypt the body encryption key. The second access key is stored in a secure location, to be retrieved in situations when the key encryption key is inaccessible.

20 Claims, 8 Drawing Sheets



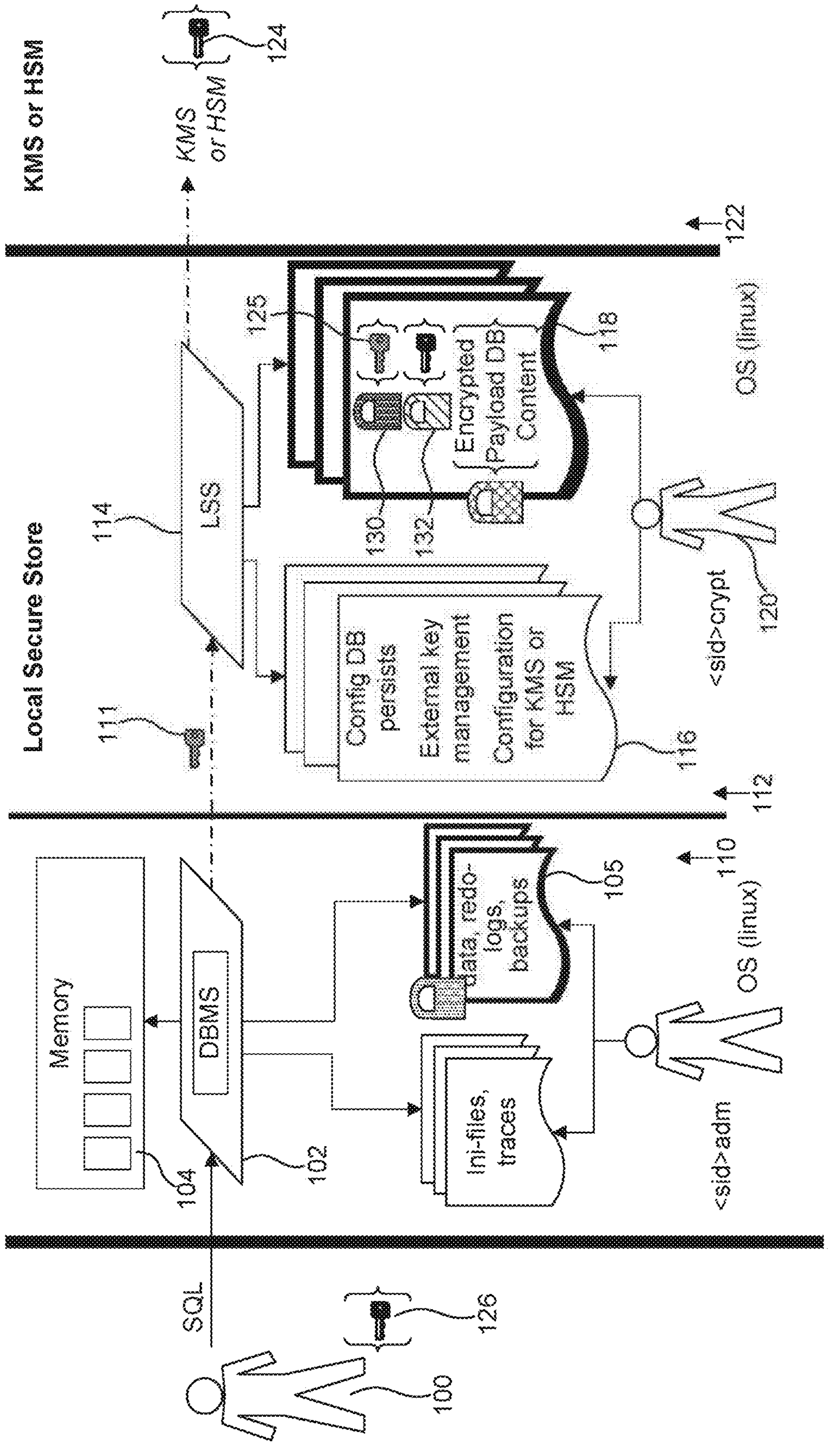

KMS or HSM
KMS or HSM
124
Local Secure Store
111
114
LSS
125
122
Config DB persists
External key management
Configuration for KMS or HSM
116
Encrypted Payload DB Content
118
130
132
<sid>crypt
120
OS (linux)
112
Memory
104
DBMS
102
data, redo-logs, backups
105
110
Ini-files, traces
OS (linux)
<sid>adm
SQL
126
100

FIG. 1

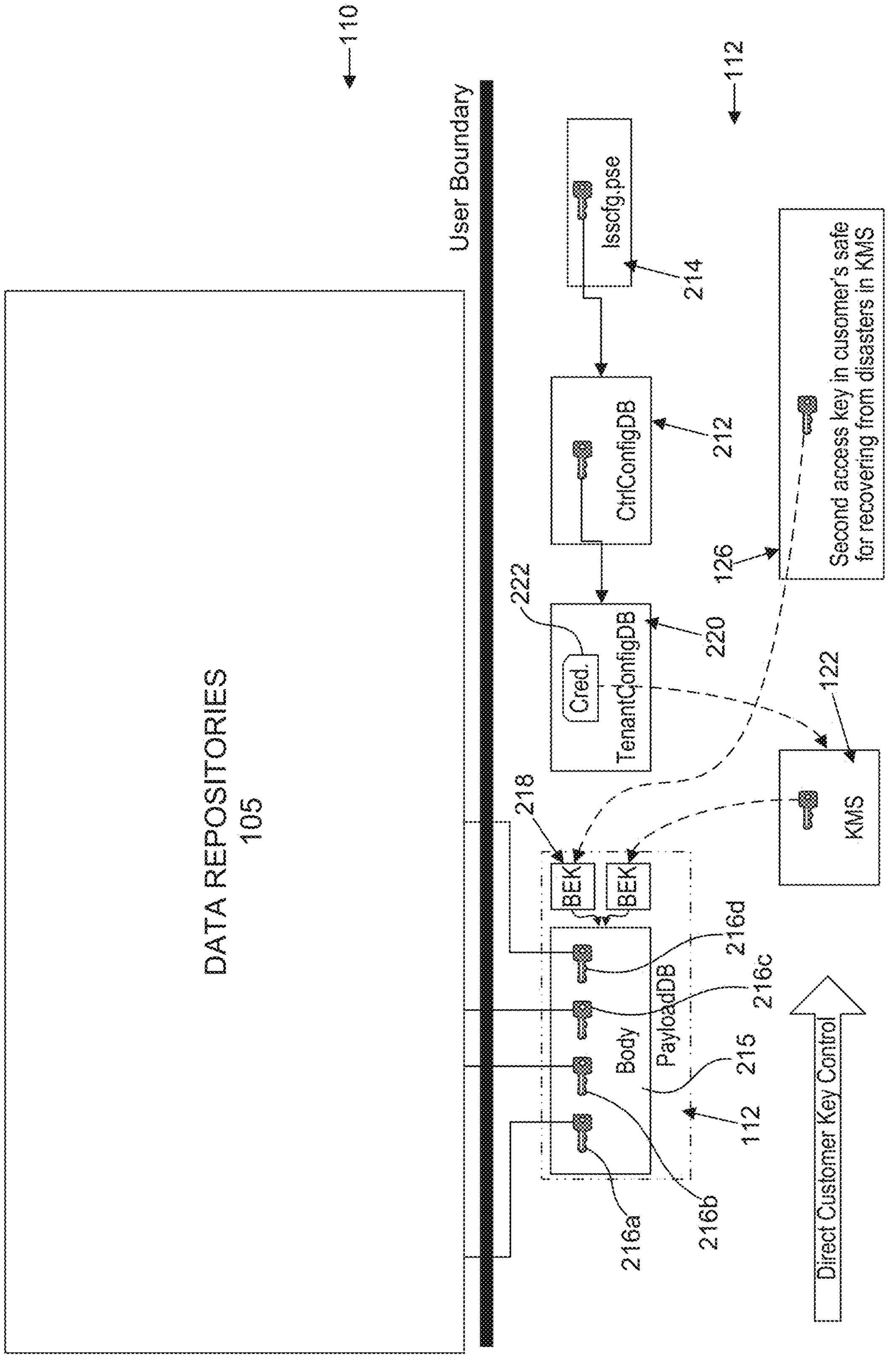

110
DATA REPOSITORIES
105
User Boundary
112
lsscfg.pse
214
CtrlConfigDB
212
Second access key in cusomer's safe for recovering from disasters in KMS
126
222
Cred.
TenantConfigDB
220
122
KMS
218
BEK
BEK
216d
216c
Body
PayloadDB
215
112
216a
216b
Direct Customer Key Control

FIG. 2

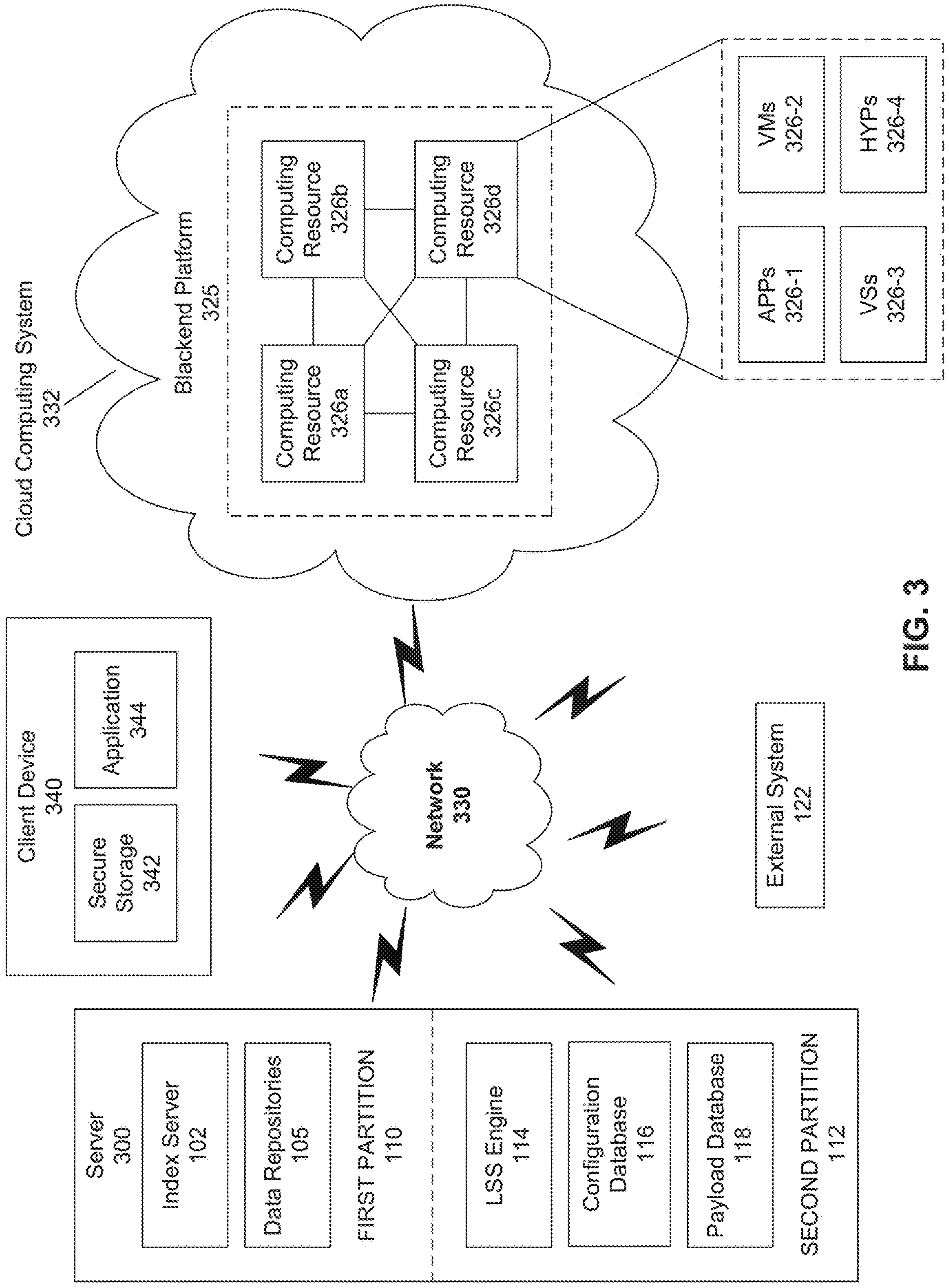

Cloud Computing System 332
Blackend Platform 325
Computing Resource 326a
Computing Resource 326b
Computing Resource 326c
Computing Resource 326d
APPs 326-1
VMs 326-2
VSs 326-3
HYPs 326-4
Client Device 340
Secure Storage 342
Application 344
Network 330
External System 122
Server 300
Index Server 102
Data Repositories 105
FIRST PARTITION 110
LSS Engine 114
Configuration Database 116
Payload Database 118
SECOND PARTITION 112

FIG. 3

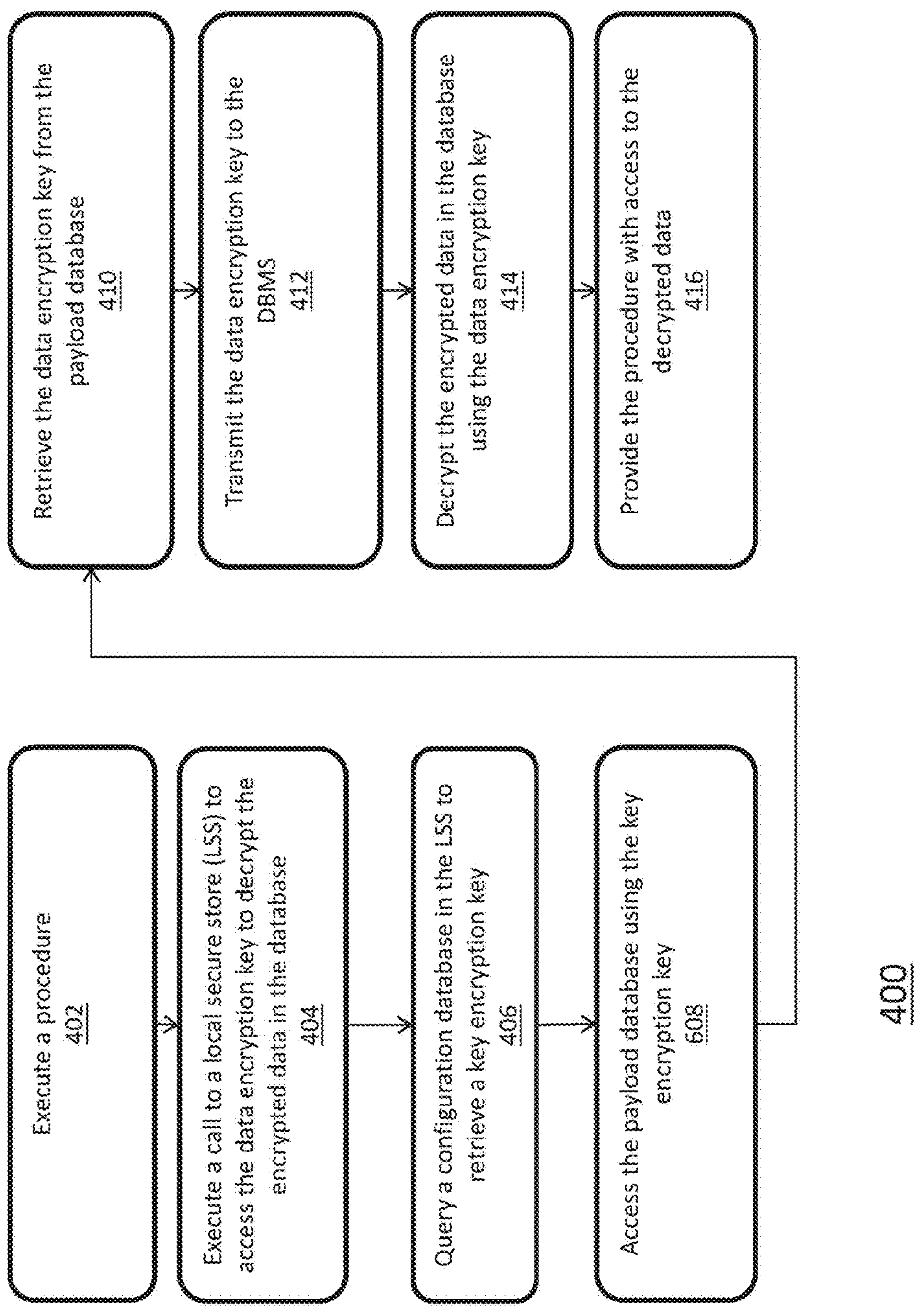

Execute a procedure
402
Execute a call to a local secure store (LSS) to access the data encryption key to decrypt the encrypted data in the database
404
Query a configuration database in the LSS to retrieve a key encryption key
406
Access the payload database using the key encryption key
608
Retrieve the data encryption key from the payload database
410
Transmit the data encryption key to the DBMS
412
Decrypt the encrypted data in the database using the data encryption key
414
Provide the procedure with access to the decrypted data
416
400

FIG. 4

500

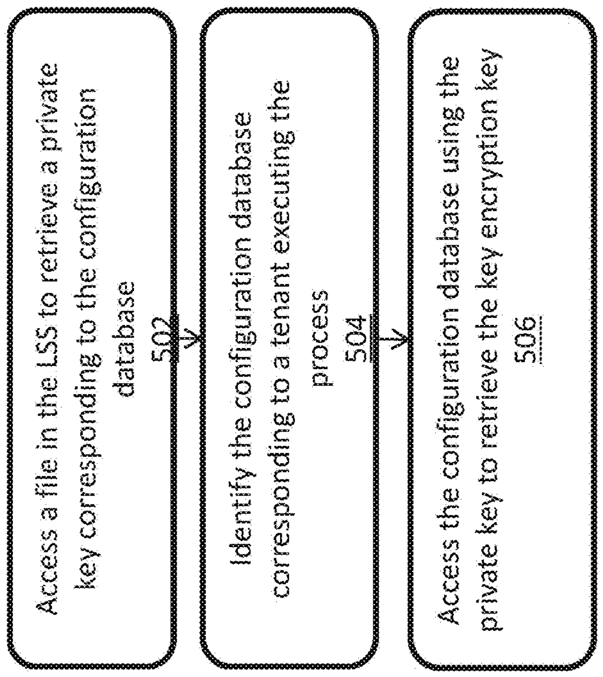

Access a file in the LSS to retrieve a private key corresponding to the configuration database
502
Identify the configuration database corresponding to a tenant executing the process
504
Access the configuration database using the private key to retrieve the key encryption key
506

FIG. 5

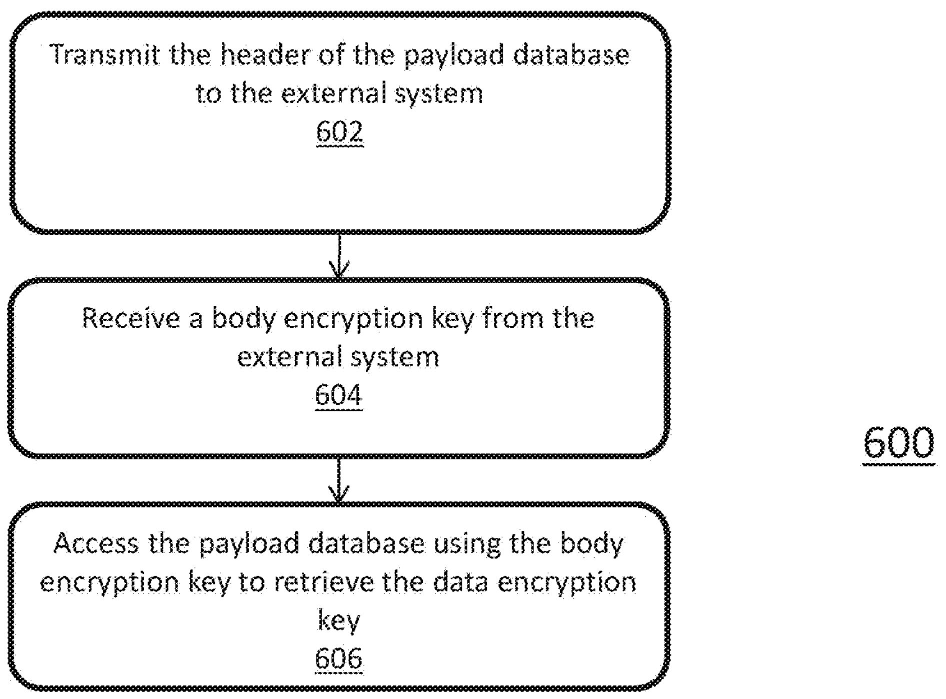

600
Transmit the header of the payload database to the external system 602
Receive a body encryption key from the external system 604
Access the payload database using the body encryption key to retrieve the data encryption key 606

FIG. 6

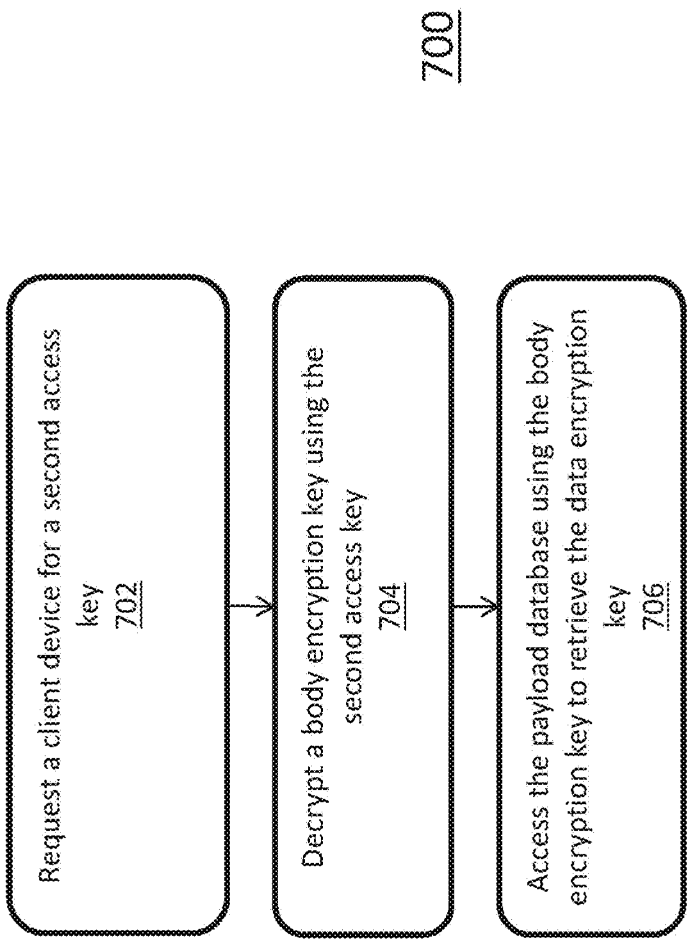

700
Request a client device for a second access key
702
Decrypt a body encryption key using the second access key
704
Access the payload database using the body encryption key to retrieve the data encryption key
706

FIG. 7

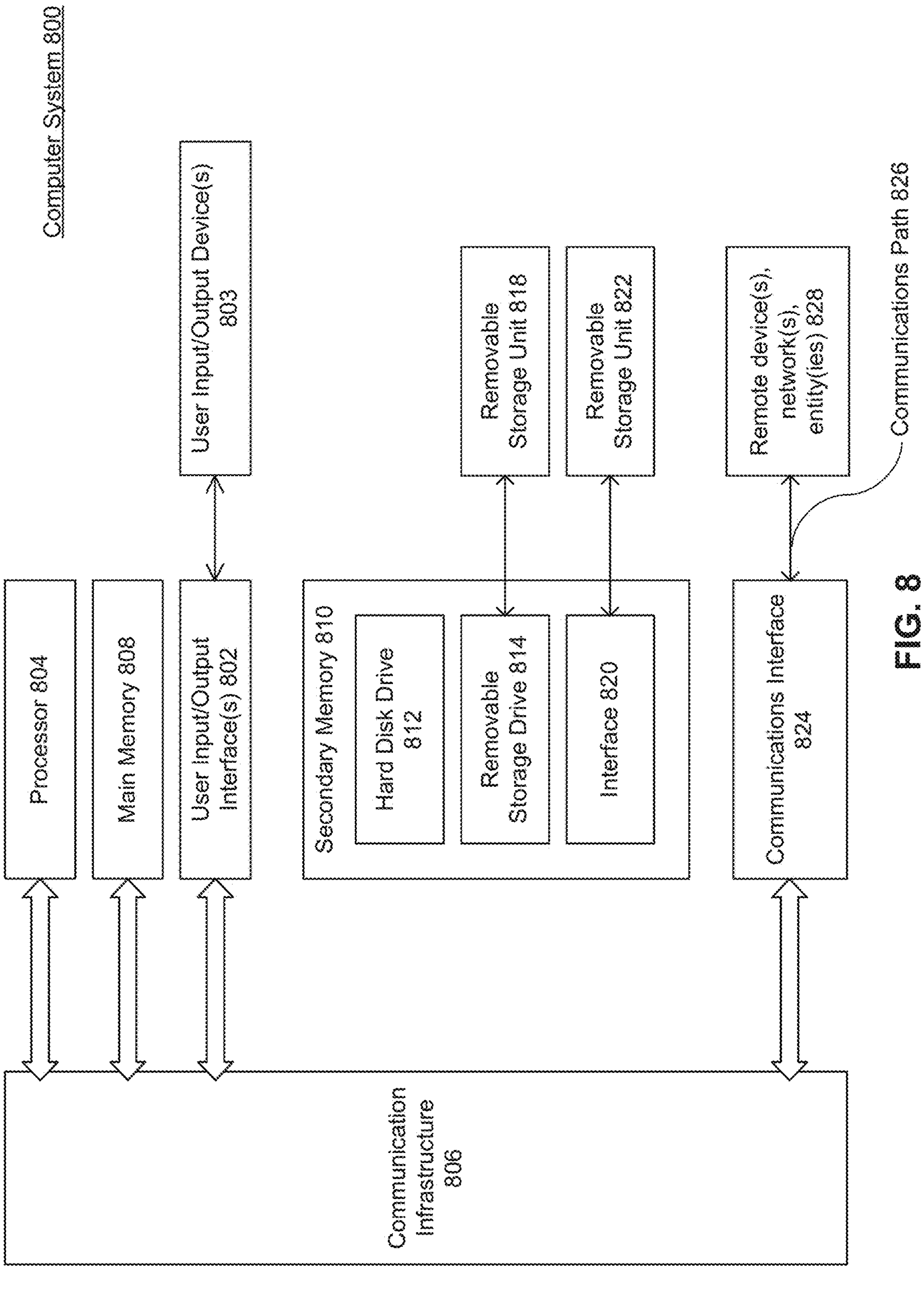

Computer System 800
Processor 804
Main Memory 808
User Input/Output Interface(s) 802
User Input/Output Device(s) 803
Secondary Memory 810
Hard Disk Drive 812
Removable Storage Drive 814
Interface 820
Removable Storage Unit 818
Removable Storage Unit 822
Communications Interface 824
Remote device(s), network(s), entity(ies) 828
Communications Path 826
Communication Infrastructure 806

FIG. 8

SYSTEM AND METHOD FOR UNLOCKING AN ENCRYPTION KEY CHAIN WITHOUT COMPROMISING SECURITY

BACKGROUND

Databases used to store sensitive data may employ a form of encryption as a way of protecting the data. A common form of encryption that is often is used is asymmetric encryption. Asymmetric encryption uses key pairs to encrypt data. The key pair includes a public key to encrypt the data and a private key to decrypt the data. Anyone accessing the data would be required to use a private key, or similar mechanism, in order to decrypt the data for read access.

Entities such as corporations or companies may encrypt sensitive data stored in a database using the public key and store the private key in a secure location. The entities may provide certain users who have the appropriate privileges or clearances, with access to the private key to decrypt the encrypted data stored in the database. Likewise, the entities may also prevent certain users who do not have the appropriate privileges or clearances, from gaining access to the private key so they would not be able to decrypt the encrypted data.

In conventional systems, entities may store the encryption keys in a secure location that is accessible to any user who has access to the database itself, irrespective of whether the user has the appropriate privileges or clearances. This creates security risks as a user (such as a database or system administrator) who has access to the database but does not have the appropriate privileges or clearances may access to the private key and use the encryption key to decrypt the encrypted data stored in the database.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the embodiments of the present disclosure, and together with the description, further serve to explain the principles of the embodiments and enable a person skilled in the pertinent art to make and use the embodiments, individually, or as a combination thereof.

FIGS. **1-2** are block diagrams of a system for unlocking an encryption key chain according to an example embodiment.

FIG. **3** is a block diagram of an example environment in which systems and/or methods described herein may be implemented according to an example embodiment.

FIG. **4** is an example flowchart illustrating a process for accessing a data encryption key to decrypt data according to an embodiment.

FIG. **5** is an example flowchart illustrating a process for accessing a configuration database according to an embodiment.

FIG. **6** is an example flowchart illustrating a process for retrieving a body encryption key from an external system according to an embodiment.

FIG. **7** is an example flowchart illustrating a process for accessing the payload database using a second access key according to an embodiment.

FIG. **8** is a block diagram of example components of a computing system according to an embodiment.

In the drawings, like reference numbers generally indicate identical or similar elements. Additionally, generally, the

left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

Provided herein are system, apparatus, device, method and/or computer program product embodiments, and/or combinations and sub-combinations thereof for accessing private keys.

Databases may store sensitive data which may be encrypted using various encryption techniques such as symmetric or asymmetric encryption. The data may be decrypted using a private key or a symmetric key.

Furthermore, external Key Management Systems (KMS) or Hardware Security Modules (HSM) may be used to manage private keys for decrypting the data stored in the database. However, a user may be unable to decrypt the data if the private key is lost or is damaged so that it can't be used for decryption anymore, if the provider of the external key management system goes out of business, if the provider gets compromised in a way that the private key is unusable (internal or external threats, crypto hijacking, . . .), or if the key gets lost before a backup is made on the external system.

The system described herein provides for bifurcating the databases and the storage of the private keys into two separate partitions. The first partition may include a database management system (DBMS) and the databases while the second partition may be a Local Secure Store (LSS) including a configuration database and a payload database. Accounts associated with the first partition may not have visibility or access to the second partition. Accounts associated with the second partition may not have visibility or access to the first partition. By doing so, the database administrator may not have access to decrypted data and may be able to handle/resolve database errors or exceptions. Likewise, an LSS system administrator may not be able to view the encrypted data but may be able to handle/resolve errors or exceptions generated in the LSS.

The payload database may be encrypted using a symmetric key. The symmetric key may be a body encryption key. The body encryption key may be encrypted two separate times using an asymmetric key pair. In the first instance in which the body encryption key is encrypted, a private key, key encryption key, may be generated. In the second instance in which the body encryption key is encrypted, a private key, second access key, may be generated. Either the key encryption key or the second access key may decrypt the body encryption key.

The body encryption key may decrypt the contents of the payload database. The configuration database may provide the key encryption key for decrypting the body encryption key. The payload database may store a data encryption key for decrypting the data in the databases.

Alternatively, an external system may store the key encryption key for decrypting the body encryption key. The external system may receive encrypted header information of the payload database storing the body encryption key and decrypt the header information to access the body encryption key using the key encryption key of the payload database. The external system may provide the body encryption key for accessing the contents of the payload database.

Furthermore, a second access may be used to decrypt the body encryption key. A client may store this second access key in a secure location. In the event the external system is inaccessible, the client may use the second access key to decrypt the body encryption key to access the payload database. For example, the client may use the second access key if the key encryption key stored by the external system is lost or is damaged so that it can't be used for decryption anymore, if the provider of the external key management system goes out of business, if the provider gets compromised in a way that the private key is unusable (internal or external threats, crypto hijacking, . . .), or if the key encryption key gets lost before a backup is made on the external system. By doing so, the client does not have to worry about not being able to decrypt the data due to the external system failing to decrypt the body encryption key.

FIGS. **1-2** are block diagrams of a system unlocking an encryption key chain according to an example embodiment. With reference to FIG. **1**, the system may include a client **100**, a DBMS **102**, memory **104**, data repositories **105**, ini-files **106**, and database administrator account **108**. The DBMS **102**, memory **104**, data repositories **105**, ini-files **106**, and database administrator account **108**, may be located in a first partition **110** of a computing system. The ini-files **106** may include configuration information for the data repositories **105**. The system may further include a second partition **112** of the computing system. The second partition **112** of the computing system may be a local secure store (LSS) configured to store private keys for decrypting encrypted data stored in data repositories. The second partition **112** may include an LSS engine **114**, configuration database **116**, payload database **118**, and LSS system administrator account **120**. The system may further include an external system **122** such as a key management system (KMS) or hardware security module (HSM). The external system **122** may be configured to manage private keys.

In an embodiment, the data stored in the data repositories **105** may be encrypted. In one example, the data may be encrypted using symmetric encryption or asymmetric encryption. The data may be decrypted using a data encryption key **111**. The data encryption key **111** may be a private key or a symmetric key. The system administrator account **108** may be tied to a database administrator configured to provide maintenance to the data repositories **105**. However, the database administrator may have visibility into the encrypted data stored in the data repositories **105**. The system administrator account **108** may not have access or visibility into the second partition **112** including the LSS engine **114**, configuration database **116**, and payload database **118**. In this regard, the system administrator account **108** may not have access to the data encryption key **111** to decrypt the data stored in the data repositories **105**.

The payload database **118** may store the data encryption key **111** used to decrypt the data stored in the data repositories **105**. The payload database may store also store certificates, settings, or other configuration information associated with the data stored in the data repositories **105**. The payload database **118** may be encrypted using symmetric encryption. A body encryption key **125** may be required to access the payload database **118**. The body encryption key **125** used to decrypt the contents of the payload database **118** may be encrypted in two different instances using asymmetric encryption. The body encryption key **125** may be stored in the header information of the payload database **118**. The header information may be encrypted in two instances, resulting in encrypted header information **130** and encrypted header information **132**. A private key, key encryption key **124**, stored by the external system **122** or configuration database **116**, may be used to decrypt the encrypted header information **130** to access the body encryption key **125**. A private key, second access key **126**, stored in a secure location by the client, may be used to decrypt the header information **132** to access the body encryption key **125**. In this regard, the body encryption key **125** may be accessed using either the key encryption key **124** or the second access key **126**.

The LSS system administrator account **120** may be tied to a LSS system administrator who manages the LSS. The LSS administrator account **120** may have visibility to the private keys stored in second partition **112**. The LSS administrator account **120** may not access or have visibility into the first partition **110** including the DBMS **102**, memory **104**, data repositories **105**, and ini-files **106**.

The client **100** may maintain storage to the second access key **126**. In the event, the key encryption key **124** is inaccessible to the client **100**, the client use the second access key **126** to decrypt the encrypted header information **132** including the body encryption key **125**. The body encryption key **125** may decrypt the contents of the payload database **118**. The second access key **126** may be generated by the client **100**. Alternatively, the second access key **126** may be generated and provided to the client. The second access key **124** may be embedded in a QR code, included in a link, or in a document. The second access key **124** may be stored by the client **100** in a secure environment. The second access key **124** may be stored in a virtual vault, jailed environment, physical vault, and/or the like.

In an embodiment, the DBMS **102** may execute a procedure. The procedure may attempt to access the encrypted data stored in the data repositories **105**. The procedure may be executed in response to a request transmitted by the client **100**. Alternatively, the procedure may be executed automatically. In response to the procedure attempting to access the data stored in the data repositories, the procedure may execute a call to the local secure store (LSS) in the second partition **112**.

The LSS engine **114** may receive the call, including a request to access the data encryption key **111** to decrypt the encrypted data in the data repositories **105**. The call may be transmitted through abstract sockets. The data encryption key **111** may be stored in the payload database **118**. The LSS engine **114** may attempt to retrieve the key encryption key **124** to access the payload database **118** using the configuration database **116**. The configuration database **116** may be encrypted using asymmetric encryption. The LSS engine **114** may access a file stored in the second partition **112** to retrieve a private key to decrypt the contents of the configuration database **116**.

In an embodiment, the configuration database **116** may store the key encryption key **124** for accessing the payload database **118**. In response to decrypting and accessing the configuration database **116**, the LSS engine **114** may retrieve the key encryption key **124**. The LSS engine **124** may use the key encryption key **124** to decrypt the encrypted header information **130** to access the body encryption key **125**. The body encryption key **125** may be used to decrypt and access the contents of the payload database **118**. The LSS engine **114** may retrieve the data encryption key **111** and transmit the data encryption key **111** to the DBMS **102**. In an embodiment, the LSS engine **114** may also retrieve certificates or settings associated with the data stored in the data repositories **105**, from the payload database **118**. The certificates or settings may be configurations. The LSS engine **114** may transmit the certificates or settings along with the data encryption key **111**. The DBMS **102** may use the data encryption key **111** to decrypt the data stored in the data repositories **105**. The DBMS **102** may also use the certificates or settings to access the data in the data repositories **105**.

In an embodiment, the configuration database **116** may store a configuration for accessing the key encryption key **124** from the external system **122**. The configuration may be a link for accessing the external system **122**. The LSS engine **114** may access the external system **122** using the configuration and transmit encrypted header information **130** for the payload database **118** to the external system **122**. The external system **122** may decrypt the encrypted header information **130** using the key encryption key **124** to access the body encryption key **125**. The external system **122** may transmit the body encryption key **125** to the LSS engine **114**. The LSS engine **114** may use the body encryption key **125** to decrypt and access the data encryption key **111** stored in the payload database **118**. In an embodiment, the LSS engine **114** may also retrieve certificates or settings associated with the data stored in the data repositories **105**, from the payload database **118**. The certificates or settings may be configurations. The LSS engine **114** may transmit the certificates or settings along with the data encryption key **111** stored in the payload database **118**. The DBMS **102** may use the data encryption key **111** to decrypt the data stored in the data repositories **105**. The DBMS **102** may also use the certificates or settings to access the data in the data repositories **105**.

In an embodiment, the LSS engine **114** may be unable to access the external system **122** for reasons described above. In this case, the DBMS **102** may request the second access key **126** from the client **100**. The second access key may be copied from the client **100** to a directory readable by a LSS system administrator. The LSS engine **114** may access the second access key **126** and use the second access key **126** to decrypt the encrypted header information **132** to retrieve the body encryption key **125**. The LSS engine **114** may use the body encryption key **125** to decrypt and access the data encryption key **111** stored in the payload database **118**. In an embodiment, the LSS engine **114** may also retrieve certificates or settings associated with the data stored in the data repositories **105**, from the payload database **118**. The certificates or settings may be configurations. The LSS engine **114** may transmit the certificates or settings along with the data encryption key **111** stored in the payload database **118**. The DBMS **102** may use the data encryption key **111** to decrypt the data stored in the data repositories **105**. The DBMS **102** may also use the certificates or settings to access the data in the data repositories **105**.

In an embodiment, the data repositories **105** may include multiple tenants. The second partition **112** may store multiple configuration databases **116** and multiple payload databases **118**, each corresponding to a tenant. For example, the DBMS **102** may execute a procedure. The procedure may attempt to access the encrypted data stored in the data repositories. In response to the procedure attempting to access the data stored in the data repositories, the procedure may execute a call to the local secure store in the second partition **112**. The procedure may indicate the tenant of the data repositories **105**.

The payload database **118** may store the data encryption key **111** for decrypting the corresponding tenant of the data repositories **105**. The key encryption key **124** and body encryption key **125** may also correspond to the tenant of the data repositories **105**. The configuration database **116** may include tenant configuration databases corresponding to each of the respective tenants.

With reference to FIG. **2**, a first partition **110** of a computing system may include data repositories **105**. The data stored in the data repositories may be encrypted and may be decrypted or accessed using a data encryption key.

The data in the data repositories may be encrypted using symmetric or asymmetric encryption. The data encryption key may be a private key or symmetric key.

A second partition **112** of the computing system may be an LSS. The second partition **112** may include a configuration database (as shown in FIG. **1** **116**). The configuration database may include a file **214**, controller configuration database **212**, and a tenant configuration database **220**. The tenant configuration database **220** may include credentials or a configuration **222** to access an external system **122**. The second partition **112** may further include a payload database **118**.

In an embodiment, the first partition **110** and the second partition **112** may be bifurcated from each other. The first partition **110** and second partition **112** may be isolated from each other such that the accounts associated with the first partition **110** may not have access or visibility into the second partition **112** and vice versa.

In response to a procedure being executed by a DBMS, the procedure may attempt to access data repositories **105**. As the data in the data repositories **105** may be encrypted, the procedure may attempt to retrieve the data encryption key from the second partition **112** (LSS). The data repositories **105** may include different data storage devices and different tenants. The data encryption key may correspond to any one of the data storage devices or different tenants. The procedure may identify which of the data storage device is being accessed and for which tenant.

The file **214** may be accessed to retrieve a private key to decrypt and access the configuration database. In response to accessing the configuration database, the controller configuration database **212** may identify the tenant configuration database **220** corresponding to the identified tenant. The controller configuration database **212** may decrypt and access the tenant configuration database **220**.

As described above, the body encryption key for accessing the payload database **118** may be encrypted. In an embodiment, the body encryption key is stored in header information of the payload database **118**. The header information is encrypted in two instances resulting in encrypted header information **130** and encrypted header information **132**. The encrypted header information **130** may be encrypted using a public key of a first asymmetric key pair. The encrypted header information **132** may be encrypted using a public key of a second asymmetric key pair. Both the encrypted header information **130** and encrypted header information **132** include the body encryption key. The first asymmetric key pair may include a private key, key encryption key, stored in either the external system **122** or the tenant configuration database **220** for decrypting the encrypted header information **130** storing the body encryption key. The second asymmetric key pair may include a private key, second access key, stored by a client for decrypting the encrypted header information **132** including the body encryption key.

In an embodiment, the tenant configuration database **220** may store the key encryption key for decrypting the encrypted header information **130** including the body encryption key. The body encryption key may be used for decrypting and accessing the contents of the payload database **118**. In another embodiment, the tenant configuration database **220** may include a configuration **222** for accessing the external system **122**. The external system **122** may store the key encryption key for decrypting and accessing the body encryption key. The encrypted header information **130** of the payload database **118** may be transmitted to the external system **122**. The external system **122** may use the key encryption key to decrypt the encrypted header information **130** to access the body encryption key. The external system **122** may transmit the body encryption key, in clear text, to the second partition **112**. The second partition may decrypt the payload database **118** using the body encryption key.

In an embodiment, the client may store a second access key **126** in a secure location. In the event the external system **122** may not be accessed, the second access key **126** to decrypt the encrypted header information **132** to access the body encryption key. The body encryption key may be used to decrypt the contents of the payload database **118**.

The payload database **118** may store data encryption keys **216***a-d* in the body **215**. As described above, the data encryption keys **216***a-d* may be private or symmetric keys to decrypt the data stored in the data repositories **105**. Each of the data encryption keys **216***a-d* may provide access to a different data storage device or may correspond to a different tenant. In this regard, the body encryption key may provide access to the corresponding data storage device or tenant identified by the procedure. The corresponding data encryption key may be transmitted to the first partition to decrypt the data of the respective data storage device or tenant.

FIG. **3** is a block diagram of an example environment in which systems and/or methods described herein may be implemented. The environment may include a server **300**, a client device **340**, an external system, a backend platform **325**, a cloud computing environment **332**, and a network **330**. The devices of the environment may be connected through wired connections, wireless connections, or a combination of wired and wireless connections.

In an example embodiment, one or more portions of the network **330** may be an ad hoc network, an intranet, an extranet, a virtual private network (VPN), a local area network (LAN), a wireless LAN (WLAN), a wide area network (WAN), a wireless wide area network (WWAN), a metropolitan area network (MAN), a portion of the Internet, a portion of the Public Switched Telephone Network (PSTN), a cellular telephone network, a wireless network, a WiFi network, a WiMax network, any other type of network, or a combination of two or more such networks.

The backend platform **325** may include one or more devices configured to host the application **344** and the LSS engine **114**. The backend platform **325** may include a server or a group of servers. In an embodiment, the backend platform **325** may be hosted in a cloud computing environment **332**. It may be appreciated that the backend platform **325** may not be cloud-based, or may be partially cloud-based.

The server **300** may include a first partition **110** of a computing system and a second partition **112** of the computing system. As a non-limiting example, operating system may be Linux®. The first partition **110** may include a DBMS **102** and data repositories **105**. The second partition **112** may include an LSS engine **114**, a configuration database **105** and a payload database **118**. The LSS engine **114** may be an executable application configured to retrieve encryption keys from the configuration database **105** and payload database **118**.

The client device **340** may include a secure storage **342** and an application **344**. The secure storage **342** may be configured securely store a second access key. The application **344** may be an executable application configured to interface with the DBMS **102**.

Each computing resource **326***a-d* includes one or more personal computers, workstations, computers, server devices, or other types of computation and/or communication devices. The computing resource(s) **326***a-d* may host the backend platform **325**. The cloud resources may include compute instances executing in the computing resources **326***a-d*. The computing resources **326***a-d* may communicate with other computing resources **326***a-d* via wired connections, wireless connections, or a combination of wired or wireless connections.

Computing resources **326***a-d* may include a group of cloud resources, such as one or more applications ("APPs") **326-1**, one or more virtual machines ("VMs") **326-2**, virtualized storage ("VS") **326-3**, and one or more hypervisors ("HYPs") **326-4**.

Application **326-1** may include one or more software applications that may be provided to or accessed by user device **310** or the client device **360**. In an embodiment, the messaging platform **100** may be executed locally on the client device **360** and the messaging platform **312** may be executed locally on the user device **310**. Alternatively, the application **326-1** may eliminate a need to install and execute software applications on the user device **310** and client device **360**. The application **326-1** may include software associated with backend platform **325** and/or any other software configured to be provided across the cloud computing environment **332**. The application **326-1** may send/receive information from one or more other applications **326-1**, via the virtual machine **326-2**.

Virtual machine **326-2** may include a software implementation of a machine (e.g., a computer) that executes programs like a physical machine. Virtual machine **326-2** may be either a system virtual machine or a process virtual machine, depending upon the use and degree of correspondence to any real machine by virtual machine **326-2**. A system virtual machine may provide a complete system platform that supports execution of a complete operating system (OS). A process virtual machine may execute a single program and may support a single process. The virtual machine **326-2** may execute on behalf of a user and/or on behalf of one or more other backend platforms **325**, and may manage infrastructure of cloud computing environment **332**, such as data management, synchronization, or long duration data transfers.

Virtualized storage **326-3** may include one or more storage systems and/or one or more devices that use virtualization techniques within the storage systems or devices of computing resource **326***a-d*. With respect to a storage system, types of virtualizations may include block virtualization and file virtualization. Block virtualization may refer to abstraction (or separation) of logical storage from physical storage so that the storage system may be accessed without regard to physical storage or heterogeneous structure. The separation may permit administrators of the storage system flexibility in how administrators manage storage for end users. File virtualization may eliminate dependencies between data accessed at a file level and location where files are physically store. This may enable optimization of storage use, server consolidation, and/or performance of non-disruptive file migrations.

Hypervisor **326-4** may provide hardware virtualization techniques that allow multiple operations systems (e.g., "guest operating systems") to execute concurrently on a host computer, such as computing resource **326***a-d*. Hypervisor **326-4** may present a virtual operating platform to the guest operating systems, and may manage the execution of the guest operating systems multiple instances of a variety of operating systems and may share virtualized hardware resources.

In an embodiment, the data repositories **105** may store encrypted data. The data may be decrypted using a data encryption key stored in the payload database **118**. The contents of the payload database **118** may be decrypted using a body encryption key. The body encryption key of the payload database **118** may be encrypted two separate times. In an embodiment, the body encryption key is stored in header information of the payload database **118**. The header information is encrypted in two instances resulting in a first encrypted header information and a second encrypted header information. The first encrypted header information is encrypted using a public key of a first asymmetric key pair. The private key of the first asymmetric key pair may be the key encryption key. The key encryption key may be used for decrypting the first encrypted header information for accessing the body encryption key. The key encryption key may be stored in an external system **122** or in the configuration database **116**.

The second encrypted header information may be encrypted using a public key of a second asymmetric key pair. The private key of the second asymmetric key pair may be a second access key. The second access key may be used to decrypt the second encrypted header information to access the body encryption key. The second access key may be stored in the secure storage **342** of the client device **340**. As a non-limiting example, an asymmetric key pair including the second access key may be generated as follows:

```
sapgenpse get_pse -a RSA:2048:SHA256 -x CustomerSecretPassphrase1 -p secondAccessKey.pse -noreq CN=Customer1
```

The public key of the asymmetric key pair is provided as a self-signed certificate that is part of the external key management configuration passed to the DBMS **102**. The DBMS **102** forwards this certificate to LSS, which uses it to encrypt the body encryption key for encrypting the contents of the payload database **118**. The client device may export the certificate with public key to file "secondAccessCertificate.pem" as follows:

```
sapgenpse export_own_cert -p secondAccessKey.pse -x CustomerSecretPassphrase1 -o secondAccessCertificate.pem
```

The client device may store the second access key in a secure location such as the secure storage **342** as follows:

```
sapgenpse export_p8 -x CustomerSecretPassphrase1 -p secondAccessKey.pse secondAccessPrivateKey.pem
```

Once the client's second access key and passphrase are stored the PSE file may be deleted.

A client may use the application **344** to interface with the DBMS **102**. The application **344** may be a SQL client. The DBMS **102** may be a HANA index server. The DBMS may include an external system key management configuration. The external system **122** may be a key management system (KMS). A KMS may generate, distribute, and manage cryptographic keys for devices and applications. The KMS includes the backend functionality for key generation, distribution, and replacement as well as the client functionality for injecting keys, storing and managing keys on devices. The external system **122** may also be a hardware security module (HSM). The HSM a physical computing device that safeguards and manages digital keys.

The DBMS **102** may enable the fail-safe key in the external system **122** key management configuration as follows:

```
settingsJSON = {
<KMS specific configuration goes here>
```

-continued

```
"credentials": {
"second_access_certificate" : "-----BEGIN CERTIFICATE-----
<certificate content base64 encoded>
-----END CERTIFICATE-----"
}
}
```

As described above, the data repositories **105** may store data for multiple different tenants. The client may log on as a specific tenant using the application **342** to add the configuration to the external system **122** for the specific tenant. The configuration may be added to the external system **122** as follows:

```
ALTER SYSTEM ADD KEY MANAGEMENT CONFIGURATION KMS_WITH_SECOND_ACCESS PROPERTIES '<settingsJSON>'
```

The configuration may be activated as follows:

```
ALTER SYSTEM ACTIVATE KEY MANAGEMENT CONFIGURATION KMS_WITH_SECOND_ACCESS
```

The client may log on to the system DB using the application **342** to add the configuration to the external system **122** for the specific tenant. The configuration may be added to the external system **122** as follows:

```
ALTER DATABASE TEN1 ADD KEY MANAGEMENT CONFIGURATION KMS_WITH_SECOND_ACCESS PROPERTIES '<settingsJSON>'
```

The configuration may be activated as follows:

```
ALTER DATABASE TEN1 ACTIVATE KEY MANAGEMENT CONFIGURATION KMS_WITH_SECOND_ACCESS
```

In an embodiment, the application **344** may execute a procedure on the DBMS **102**. The procedure may attempt to access a database of the data repositories **105** including encrypted data. The DBMS **102** may execute a call to the LSS engine **114** to access a data encryption key to decrypt the encrypted data of the database.

The LSS engine **114** may query the configuration database **116** to retrieve a key encryption key for decrypting the body encryption key of the payload database **118**. The key encryption key may be stored in the external system **122**. The configuration database **116** may store a configuration for accessing the external system **122**. The LSS engine **114** may transmit the first encryption header information and use the configuration to access the external system **122**. The external system **122** may store the key encryption key. The external system **122** may decrypt the first encrypted header information using the key encryption key to access the body encryption key. The external system **122** may transmit the body encryption key to the LSS engine **114**. The LSS engine **114** may use the body encryption key to decrypt the contents of the payload database **118**. The LSS engine **114** may retrieve the data encryption key for decrypting the database from the body of the payload database **118** and transmit the data encryption key to the DBMS **102**.

In the event of emergency situations, the external system **122** may not be accessed. The emergency system may be power outages, system crash, the external system **122** has purged, or is no longer functional, and/or the like. In these situations, the LSS engine **114** may not be able to access the external system **122**. The DBMS **102** may request the second access key from the client. The second access key may be copied from the secure storage **342** to a directory readable by a LSS system administrator. An LSS tenant may be restored as follows:

```
lssbackup -t TEN1 restoreWithSecondAccessKey
PayloadBackupFileName payload ConfigBackupFile-
   Name
SecondAccessPrivateKeyFileName.pem
```

A LSS backup passphrase may be inserted and if a passphrase for a private key may be provided if one has been generated. The LSS engine **114** may use the second access key to decrypt the second encrypted header information to access the body encryption key of the payload database **118**. The body encryption key may be used to decrypt the contents of the payload database **118**.

As described above, the configuration database **116** may also be encrypted using a public key of an asymmetric key pair. The private key may be stored in a file in the second partition **112**. The private key may be used to decrypt the contents of the configuration database **116**.

The data encryption key used to decrypt the data of the data repositories **105**, and the contents of the configuration database **116** may be rotated by the LSS engine **114** after a specified amount of time such that a new data encryption key is generated. The data of the data repositories **105** may be re-encrypted again using a new data encryption key and the configuration database contents may be encrypted again using a new asymmetric key pair. A new body encryption key to decrypt the contents of the payload database **118** may also be generated after a specified amount of time.

The asymmetric key pair for encrypting and decrypting the body encryption key is also rotated. As an example, the first asymmetric key pair for encrypting and decrypting the first encrypted header information including the body encryption key may be rotated by the external system **122** after a specified amount of time such that a new asymmetric key pair is generated. The first encrypted header information including the body encryption key is re-encrypted the new public key. Furthermore, a new key encryption key is generated and stored in the configuration database **116** or the external system **122**.

In the event a new DBMS is installed and/or the DBMS **102** is updated an installation bundle is generated. The installation bundle includes file hashes. The configuration database **116** may match up all of the existing procedures for the DBMS **102** with using a list of procedures and the file hashes in the installation bundle. By doing so, the DBMS **102** is assigned the appropriate certificates corresponding to the private keys stored in the second partition **112**.

FIG. **4** is an example flowchart **400** for accessing a data encryption key to decrypt data. It is to be appreciated the operations may occur in a different order, and some operations may not be performed. Merely as an example, the flow of data will be described with respect to FIGS. **1-3**.

In operation **402**, a DBMS may execute a procedure. The procedure may include calls to a database. Data stored inside the database may be encrypted. The encryption format may be asymmetric or symmetric. In this regard, a data encryption key may be needed to decrypt the data.

In operation **404**, the DBMS may execute a call to a local secure store (LSS) to access the data encryption key to decrypt the encrypted data in the database, in response to the procedure's attempt to access the database. The call may be executed using authentic ports. The LSS and the database are isolated from each other. That is a first system administrator of the LSS may be prevented visibility into the database. A second administrator of the database may be prevented visibility into the LSS. This way, neither the first system administrator is able to view the data stored in the database nor is the second system administrator able to view the keys stored in the LSS to decrypt the data in the database.

In operation **406**, a LSS engine may query a configuration database in the LSS to retrieve a key encryption key for accessing a payload database storing the data encryption key.

In operation **408**, the LSS engine may access the payload database using the key encryption key.

In operation **410**, the LSS engine may retrieve the data encryption key from the payload database.

In operation **412**, the LSS engine may transmit the data encryption key to the DBMS.

In operation **414**, the DBMS may decrypt the encrypted data in the database using the data encryption key.

In operation **416**, the DBMS may provide the procedure with access to the decrypted data.

FIG. **5** is an example flowchart **500** for accessing a configuration database. It is to be appreciated the operations may occur in a different order, and some operations may not be performed. Merely as an example, the flow of data will be described with respect to FIGS. **1-3**.

In operation **502**, the LSS engine may access a file in the LSS to retrieve a private key corresponding to the configuration database.

In operation **504**, the LSS engine may identify the configuration database corresponding to a tenant executing the process. For example, the database may be a multi-tenant database. The LSS may include multiple configuration databases. Each configuration database may correspond to a tenant.

In operation **506**, the LSS engine may access the configuration database using the private key to retrieve the key encryption key.

FIG. **6** is an example flowchart **600** for retrieving the body encryption key from an external system. It is to be appreciated the operations may occur in a different order, and some operations may not be performed. An LSS engine may connect with an external system to retrieve a private key for accessing the payload database. Merely as an example, the flow of data will be described with respect to FIGS. **1-3**.

In operation **602**, the LSS engine may transmit the header of the payload database to the external system.

In operation **604**, the LSS engine may receive a body encryption key from the external system accessed by decrypting the header information using the key encryption key stored at the external system.

In operation **606**, the LSS engine may access the payload database using the body encryption key to retrieve the data encryption key.

FIG. **7** is an example flowchart **700** for accessing the payload database using a second access key. It is to be appreciated the operations may occur in a different order, and some operations may not be performed. The external system may be inaccessible. Merely as an example, the flow of data will be described with respect to FIGS. **1-3**.

In operation **702**, the DBMS may request a client device for a second access key.

In operation **704**, the LSS engine may decrypt a body encryption key using the second access key.

In operation **709**, the LSS engine may access the payload database using the body encryption key to retrieve the data encryption key.

FIG. **8** is a block diagram of example components of device **800**. One or more computer systems **800** may be used, for example, to implement any of the embodiments discussed herein, as well as combinations and sub-combinations thereof. Computer system **800** may include one or more processors (also called central processing units, or

CPUs), such as a processor **804**. Processor **804** may be connected to a communication infrastructure or bus **806**.

Computer system **800** may also include user input/output device(s) **803**, such as monitors, keyboards, pointing devices, etc., which may communicate with communication infrastructure **806** through user input/output interface(s) **802**.

One or more of processors **804** may be a graphics processing unit (GPU). In an embodiment, a GPU may be a processor that is a specialized electronic circuit designed to process mathematically intensive applications. The GPU may have a parallel structure that is efficient for parallel processing of large blocks of data, such as mathematically intensive data common to computer graphics applications, images, videos, etc.

Computer system **800** may also include a main or primary memory **308**, such as random access memory (RAM). Main memory **808** may include one or more levels of cache. Main memory **808** may have stored therein control logic (i.e., computer software) and/or data.

Computer system **800** may also include one or more secondary storage devices or memory **810**. Secondary memory **810** may include, for example, a hard disk drive **812** and/or a removable storage device or drive **814**.

Removable storage drive **814** may interact with a removable storage unit **818**. Removable storage unit **818** may include a computer usable or readable storage device having stored thereon computer software (control logic) and/or data. Removable storage unit **818** may be program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM or PROM) and associated socket, a memory stick and USB port, a memory card and associated memory card slot, and/or any other removable storage unit and associated interface. Removable storage drive **814** may read from and/or write to removable storage unit **818**.

Secondary memory **810** may include other means, devices, components, instrumentalities or other approaches for allowing computer programs and/or other instructions and/or data to be accessed by computer system **800**. Such means, devices, components, instrumentalities or other approaches may include, for example, a removable storage unit **822** and an interface **820**. Examples of the removable storage unit **822** and the interface **820** may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM or PROM) and associated socket, a memory stick and USB port, a memory card and associated memory card slot, and/or any other removable storage unit and associated interface.

Computer system **800** may further include a communication or network interface **824**. Communication interface **824** may enable computer system **800** to communicate and interact with any combination of external devices, external networks, external entities, etc. (individually and collectively referenced by reference number **828**). For example, communication interface **824** may allow computer system **800** to communicate with external or remote devices **828** over communications path **826**, which may be wired and/or wireless (or a combination thereof), and which may include any combination of LANs, WANs, the Internet, etc. Control logic and/or data may be transmitted to and from computer system **800** via communication path **826**.

Computer system **800** may also be any of a personal digital assistant (PDA), desktop workstation, laptop or notebook computer, netbook, tablet, smart phone, smart watch or other wearable, appliance, part of the Internet-of-Things, and/or embedded system, to name a few non-limiting examples, or any combination thereof.

Computer system **800** may be a client or server, accessing or hosting any applications and/or data through any delivery paradigm, including but not limited to remote or distributed cloud computing solutions; local or on-premises software ("on-premise" cloud-based solutions); "as a service" models (e.g., content as a service (CaaS), digital content as a service (DCaaS), software as a service (SaaS), managed software as a service (MSaaS), platform as a service (PaaS), desktop as a service (DaaS), framework as a service (FaaS), backend as a service (BaaS), mobile backend as a service (MBaaS), infrastructure as a service (IaaS), etc.); and/or a hybrid model including any combination of the foregoing examples or other services or delivery paradigms.

Any applicable data structures, file formats, and schemas in computer system **800** may be derived from standards including but not limited to JavaScript Object Notation (JSON), Extensible Markup Language (XML), Yet Another Markup Language (YAML), Extensible Hypertext Markup Language (XHTML), Wireless Markup Language (WML), MessagePack, XML User Interface Language (XUL), or any other functionally similar representations alone or in combination. Alternatively, proprietary data structures, formats or schemas may be used, either exclusively or in combination with known or open standards.

In some embodiments, a tangible, non-transitory apparatus or article of manufacture comprising a tangible, non-transitory computer useable or readable medium having control logic (software) stored thereon may also be referred to herein as a computer program product or program storage device. This includes, but is not limited to, computer system **800**, main memory **308**, secondary memory **810**, and removable storage units **818** and **822**, as well as tangible articles of manufacture embodying any combination of the foregoing. Such control logic, when executed by one or more data processing devices (such as computer system **800**), may cause such data processing devices to operate as described herein.

Embodiments of the present invention have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries may be defined so long as the specified functions and relationships thereof are appropriately performed.

The foregoing description of the specific embodiments will so fully reveal the general nature of the invention that others may, by applying knowledge within the skill of the art, readily modify and/or adapt for various applications such specific embodiments, without undue experimentation, without departing from the general concept of the present invention. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance.

The breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A computer-implemented method comprising:

executing, by one or more computing devices, a procedure by a database management system (DBMS) attempting to access a database storing encrypted data, wherein the database resides in a first partition of a bifurcated computing system;

executing, by the one or more computing devices, a call to a local secure store (LSS) to access a data encryption key to decrypt the encrypted data in the database, in response to the procedure's attempt to access the database, wherein the LSS resides in a second partition of the bifurcated computing system and wherein the first and second partition are visually isolated from each other;

determining that an external system, external to both the LSS and the DBMS, is storing a key encryption key for accessing a payload database storing the data encryption key;

querying, by the one or more computing devices, the external system to retrieve the key encryption key for accessing the payload database;

determining that the external system is inaccessible;

determining that the payload database can be decrypted using either the key encryption key or a second access key stored separately from the key encryption key on a different system;

accessing, by the one or more computing devices, the payload database using the second access key responsive to the determining that the external system is inaccessible;

retrieving, by the one or more computing devices, the data encryption key from the payload database;

transmitting, by the one or more computing devices, the data encryption key to the DBMS;

decrypting, by the one or more computing devices, the encrypted data in the database using the second access key; and

providing, by the one or more computing devices, the procedure with access to the decrypted data.

2. The method of claim 1, in response to executing the call to the LSS to access the data encryption key, the method further comprising:

accessing, by the one or more computing systems, a file in the LSS to retrieve a private key;

identifying, by the one or more computing systems, the configuration database corresponds with a tenant indicated in the procedure; and

accessing, by the one or more computing systems, the configuration database using the private key to retrieve the key encryption key.

3. The method of claim 2, wherein the configuration database stores the key encryption key.

4. The method of claim 2, wherein the configuration database stores a configuration for connecting to an external system storing the key encryption key.

5. The method of claim 4, further comprising:

transmitting, by the one or more computing devices, header information of the payload database to the external system;

receiving, by the one or more computing devices, a body encryption key from the external system accessed by decrypting using the header information using the key encryption key; and

accessing, by the one or more computing devices, the payload database using the body encryption key to retrieve the data encryption key.

6. The method of claim 4, in response to the external system being inaccessible the method further comprising:

requesting, by the one or more computing devices, a client device for a second access key;

decrypting, by the one or more computing devices, a body encryption key using the second access key; and

accessing, by the one or more computing devices, the payload database using the body encryption key to retrieve the data encryption key.

7. The method of claim 1, wherein a first system administrator is associated with the database and a second system administrator is associated with the LSS.

8. The method of claim 7, further comprising:

preventing, by the one or more computing devices, the first system administrator visibility into the LSS; and

preventing, by the one or more computing devices, the second system administrator visibility into the database.

9. A system comprising:

a memory;

a processor copulated to the memory, the processor configured to:

execute a procedure by a database management system (DBMS) attempting to access a database storing encrypted data, wherein the database resides in a first partition of a bifurcated computing system;

execute a call to a local secure store (LSS) to access a data encryption key to decrypt the encrypted data in the database, in response to the procedure's attempt to access the database, wherein the LSS resides in a second partition of the bifurcated computing system and wherein the first and second partition are visually isolated from each other;

determine that an external system, external to both the LSS and the DBMS, is storing a key encryption key for accessing a payload database storing the data encryption key;

query the external system to retrieve the key encryption key for accessing the payload database;

determine that the external system is inaccessible;

determine that the payload database can be decrypted using either the key encryption key or a second access key stored separately from the key encryption key on a different system;

access the payload database using the second access key responsive to the determining that the external system is inaccessible;

retrieve the data encryption key from the payload database;

transmit the data encryption key to the DBMS;

decrypt the encrypted data in the database using the second access key; and

provide the procedure with access to the decrypted data.

10. The system of claim 9, in response to executing the call to the LSS to access the data encryption key, the processor further configured to:

access a file in the LSS to retrieve a private key;

identify the configuration database corresponds with a tenant indicated in the procedure, and

access the configuration database using the private key to retrieve the key encryption key.

11. The system of claim 10, wherein the configuration database stores the key encryption key.

12. The system of claim 10, wherein the configuration database stores a configuration for connecting to an external system storing the key encryption key.

13. The system of claim **12**, the processor further configured to:

transmit header information of the payload database to the external system;

receive a body encryption key from the external system accessed by decrypting the header information using the key encryption key; and

access the payload database using the body encryption key to retrieve the data encryption key.

14. The system of claim **12**, in response to the external system being inaccessible the processor further configured to:

request a client device for a second access key;

decrypt a body encryption key using the second access key; and

access the payload database using the body encryption key to retrieve the data encryption key.

15. The system of claim **9**, wherein a first system administrator is associated with the database and a second system administrator is associated with the LSS.

16. The system of claim **15**, the processor further configured to:

prevent the first system administrator visibility into the LSS; and

prevent the second system administrator visibility into the database.

17. A non-transitory computer-readable medium storing instructions that when executed by one or more processors of a device cause the one or more processors to:

execute a procedure by a database management system (DBMS) attempting to access a database storing encrypted data, wherein the database resides in a first partition of a bifurcated computing system;

execute a call to a local secure store (LSS) to access a data encryption key to decrypt the encrypted data in the database, in response to the procedure's attempt to access the database, wherein the LSS resides in a second partition of the bifurcated computing system and wherein the first and second partition are visually isolated from each other;

determine that an external system, external to both the LSS and the DBMS, is storing a key encryption key for accessing a payload database storing the data encryption key;

query the external system to retrieve the key encryption key for accessing the payload database;

determine that the external system is inaccessible;

determine that the payload database can be decrypted using either the key encryption key or a second access key stored separately from the key encryption key on a different system;

access the payload database using the second access key responsive to the determining that the external system is inaccessible;

retrieve the data encryption key from the payload database;

transmit the data encryption key to the DBMS;

decrypt the encrypted data in the database using the second access key; and

provide the procedure with access to the decrypted data.

18. The non-transitory computer readable medium of claim **17**, in response to executing the call to the LSS to access the data encryption key, the instructions cause the processor to:

access a file in the LSS to retrieve a private key;

identify the configuration database corresponds with a tenant indicated in the procedure; and

access the configuration database using the private key to retrieve the key encryption key.

19. The non-transitory computer readable medium of claim **18**, wherein the configuration database stores a configuration for connecting to an external system storing the key encryption key.

20. The method of claim **1**, wherein the second access key is embedded in a link.

* * * * *